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# Spatial Variability of Crop Growth as Affected by Contour Hedgerow Systems

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## Abstract

In the tropics, soil conservation measures to control water induced erosion have been intensively investigated in the past decades. Land management techniques such as contour hedgerow systems are very effective in erosion control but they also may lead to a pronounced spatial variability in crop response. However, our understanding of this phenomenon at field scale is still limited. This study aimed, therefore, at assessing the spatial variability in crop response under contour hedgerow systems. Data were collected from an erosion control experiment in the Loei province of Northeast Thailand established in 2003. The trial was set up on a clayey, kaolinitic, typic Haplustalf in a split plot design with five maize cropping systems as main plots and two fertiliser levels (no fertiliser and 60 and 14 kg $ha^{-1}$ of N and P, repectively) as sub-plots. Slope gradients ranged from 21-28%. From these treatments, the control without hedgerows, grass hedgerows, and leucaena hedgerows, each at both fertiliser levels, were selected to conduct this study. Maize grain yields and aboveground vegetative biomass were determined per row and related to their transect position in each plot. A simple index was used to assess the effect of contour hedgerows on crop response, indicating that contour hedgerow systems cannot always be evaluated as completely positive. The negative impact of contour hedges on maize growth in rows adjacent to the contour hedgerow was strong. Negative effects on crop growth, however, were stronger in the upper part of the alleys and in the ruzi grass treatment. Soil fertility improvement on the upper part of the alleys and a better management of the barrier strip may enhance crop productivity.

**Keywords:** *Zea mays*, *Leucaena leucocephala*, *Brachiaria rhuziziensis*, *Canavalia ensiformis,* minimum tillage, soil conservation, spatial variability, root length density, crop response index, $\delta^{13}C$ discrimination method

## Introduction

Worldwide erosion is a severe problem and important constraint of crop production on hillsides. For many farmers in the tropics, these hillsides are often the only available land resources. The underlying processes of soil erosion are well understood. Heavy rainfall associated with poor soil cover by annual crops during distinct growth stages leads to detachment of soil particles which are then transferred by runoff water and deposited down slope. In consequence, nutrient and fertility status of soils are altered across the slope in the course of time (Morgan, 2005).

Measures to control water induced erosion have been intensively investigated in the past; e.g. contour hedgerow systems provide shelter against runoff and erosion and are, thus, considered as a viable alternative to traditional cropping systems (Van Noordwijk and Verbist, 2000). Even though soil losses can be dramatically reduced by these systems, whether beneficial effects on crops will develop is often unpredictable and usually insufficient to attract widespread adoption of contour hedges. (Ong et al., 2002). The particular role of barriers in soil conservation, however, is often not clearly understood. They may lead to natural terrace formation which controls erosion effectively, but are associated with creating a pronounced spatial variability in crop response (Dercon et al., 2006).

Our own research with various hedgerow systems under minimum tillage and relay cover cropping in mountainous regions of Thailand showed astonishing results (Pansak et al., 2006). In this experiment, soil loss, runoff and induced N losses decreased over a 3-yr-period, while maize grain yields increased in the course of time regardless whether soil conservation measures were included or not. Positive effects of barrier treatments on erosion processes and yields were only observed during the first two years. In the third year, however, the performance of the control without hedgerows or barriers improved strongly, making it competitive to treatments with soil conservation. Therefore, the objectives of this study were:

(i) to assess the impact of contour hedgerow systems (barriers) on spatial variability in crop response and
(ii) to test a simple crop response index for evaluation of effectiveness of barrier systems.

## Material and Methods

The field trial was carried out at Ban Bo Muang Noi in the Loei province of Northeast Thailand (17°33' N and 101°1' E; 572 m a.s.l.). The topography at the research site is characterized by hills with slope gradients ranging from 21 to 28%.

The soil at the experimental site is a clayey, kaolinitic, typic Haplustalf with a pH of 6, low total N and available P contents, a CEC of almost 8 $cmol_c\ kg^{-1}$, and an organic matter content of 3.5% (0-15 cm). The annual precipitation is almost 1300 mm with rains falling between May and September in a monomodal pattern. The mean annual temperature is 26°C. Crop production in the research area is characterised by subsistence agriculture with paddy fields in the valleys and a combination of maize and fruit or nut trees on the uplands. On steeper slopes, upland cropping by subsistence farmers is carried in a form of minimum tillage by using a wooden stick for planting after burning.

In May 2003, the erosion control trial was established in a spilt-plot design with two replicates. Plot size was 4 m wide and 18 m long. Main plots were subdivided in two fertiliser levels, e.g. (i) no fertiliser and (ii) 60 kg $ha^{-1}$ of N and 14 kg $ha^{-1}$ of P. The subplots had five treatments, from which the following treatments were selected for this study: (i) control without hedgerows, (ii) ruzi (*Brachiaria ruzziensis* Germin et Evrand) grass barriers and (iii) leucaena (*Leucaena leucocephala* Lam.) hedges. On all plots, maize (*Zea mays* L.) cv. Suwan 1 was planted following the contour lines and by using a stick without any further soil preparation. Leucaena hedges were pruned five times a year to avoid shading of maize; all prunings were left in the alleys. In addition, jack beans (*Canavalia ensiformis* (L.) (DC) were grown between maize rows as relay crop one month prior to maize harvest. In all plots dry matter of maize and jack beans were applied as mulch in the corresponding plots.

For this study, only data from the 2005 cropping season were used, three years after establishment of the field trial. Each plot was subdivided in three sections. Data on maize grain yield were collected per row (Fig. 1).

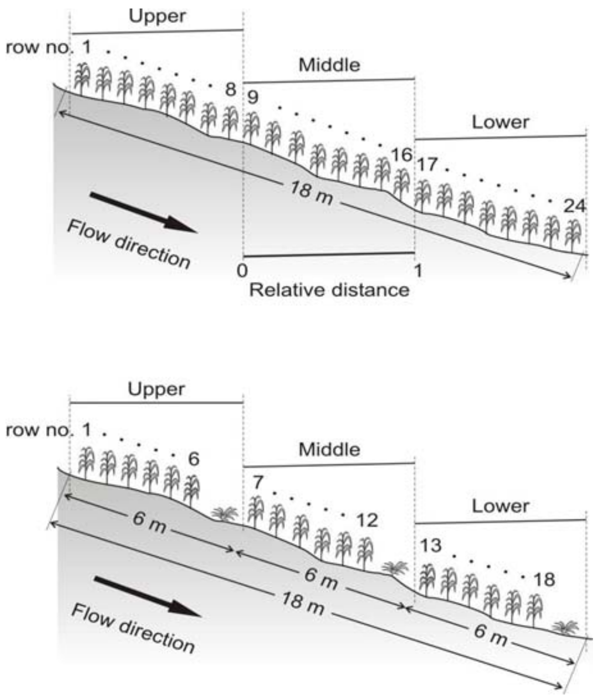


**Fig. 1.** Scheme of research plots with maize plants without hedgerows (above) and with ruzi grass barriers or leucaena hedges (below).

Root length density (RLD) was determined by using the auger sampling method 100 days after planting (Böhm, 1979). RLD of maize, ruzi grass and leuceana was assessed at four sampling positions in the middle section of plots without fertiliser application and at two depths (Fig. 2). Each sample consisted of four subsamples. Ruzi grass, leucaena and maize roots could be easily distinguished by colour and thickness of roots.

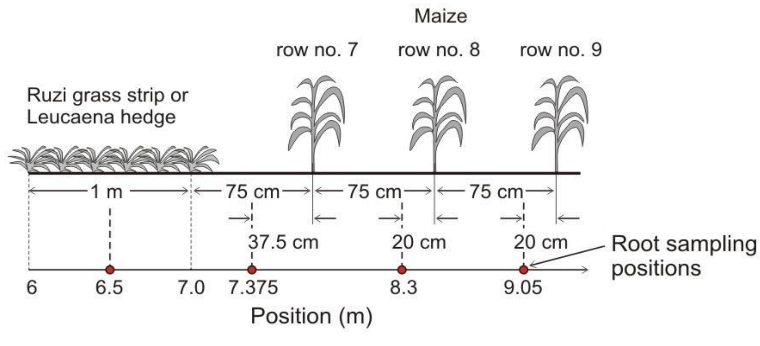


**Fig. 2.** Root sampling positions in ruzi grass barriers or leucaena hedgerows (Middle part). Root samples in the control without hedgerows were taken at corresponding positions.

The carbon isotope discrimination method was used to evaluate competition for water. Samples from the third youngest maize leaf were collected from the middle row and rows adjacent to the lower barrier at 100 days after planting (DAP). Carbon-isotope composition was determined with a Euro Elemental Analyser, coupled to a Finigan IRMS. Maize leaf samples were analysed The $\delta^{13}C$ was calculating by comparing $^{13}C$ to $^{12}C$ composition of a sample relative to the composition of the Pee Dee Belemnite standard.

To evaluate the effectiveness of barrier systems, the crop response index (CRI) proposed by Dercon et al. (2006) was used. It is defined as follows:

(1) $$\text{CRI}(\%) = \left[\frac{CR_C - CR_{0.5}}{CR_{0.5}}\right] \times 100$$

where $CR_c$ is the current crop response of the cultivated area in a contour hedgerow system and $CR_{0.5}$ is the estimated crop response based on the mid row position of the control without hedgerow. A positive CRI indicates a better crop response and a higher effectiveness of the system, while negative values point to a poor system performance.

A split-plot model was used to test the effects of fertilization and soil conservation measures on crop response and $\delta^{13}C$ values in maize at 100 DAP. Grain yield showed a clear parabolic pattern across alleys and, thus, second-order polynomial equations were used to describe the spatial variability in crop response.

## Results and Discussion

In the control maize grain yields ranged from 250 to 300 g m$^{-1}$ in plots without fertilization and from 400 to 450 g m$^{-1}$ with fertilisation along the slope (Fig. 3).

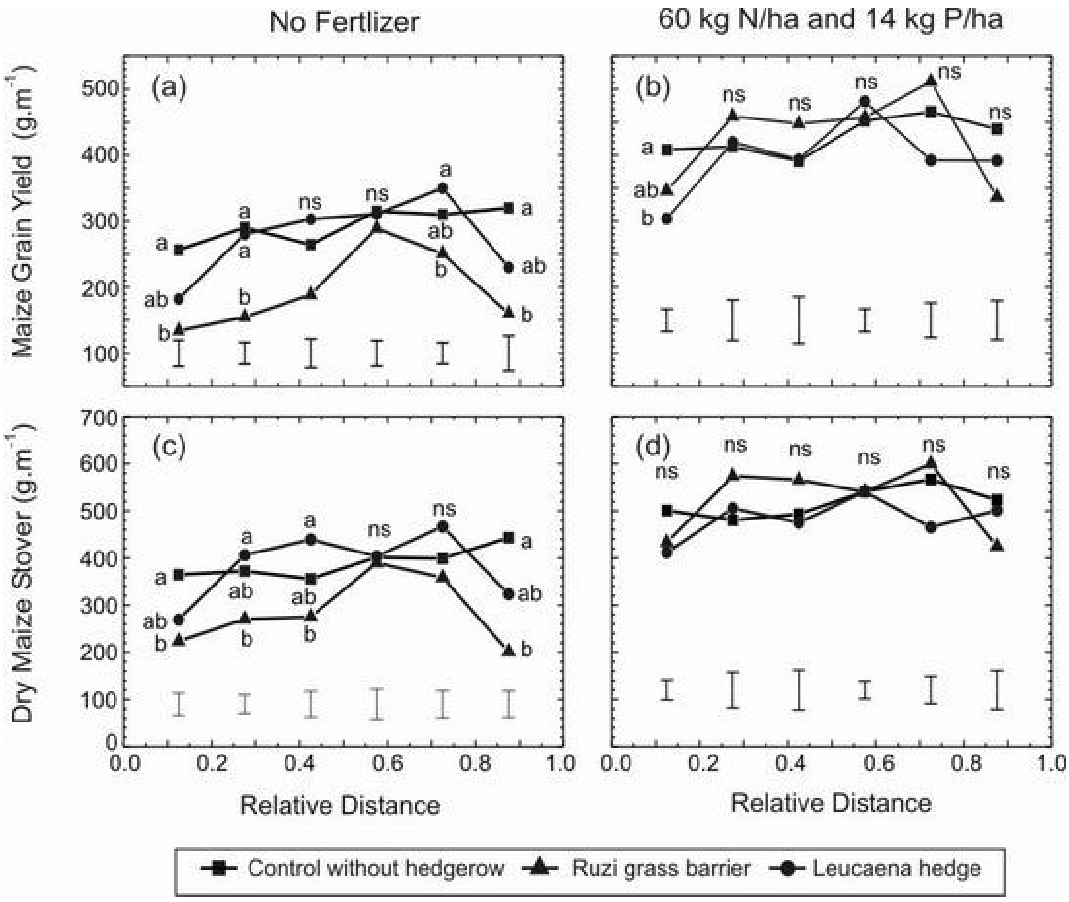


**Fig. 3.** Maize grain and stover yields per row (g m$^{-1}$) as affected by soil conseravtaion measure and fertilizer application at Ban Bo Muang Noi, Loei province, Northeast Thailand in 2005. With regard to relative distance,"Zero" indicates upper barrier or hedge and "one" lower barrier or hedge. . Data are averages of three alley.

Similar results were observed for maize stover (360 to 440 g $m^{-1}$ without fertilization and 500 to 560 g $m^{-1}$ with fertilization). On average yields were almost 50% higher when fertiliser was applied. Similar trends were observed in both soil conservation treatments. Regardless of fertilizer application, average maize grain yields of the control corresponded with values from middle rows of treatments with barriers or hedges. Maize grain yields of rows next to barriers, however, tended to have lower grain yields as compared to mid row positions.

The row wise assessment of maize grain yields indicated a strong impact of green barriers or hedges on maize yields. Therefore, the root length densities (RLD) were determined in the middle position of unfertilized plots of both soil conservation treatments. Figure 4 shows (RLD) profiles of maize for unfertilized plots with conservation measures. RLD of maize decreased towards the grass barrier. Ruzi grass RLD was high, indicating a well developed root system. Grass roots were present in the first two maize rows, strongly interfering with the maize roots. The RLD of maize near the leucaena hedge was similar to that of the mid row position. RLD of leucaena was lower than that of ruzi grass and almost in the range of maize RLD.

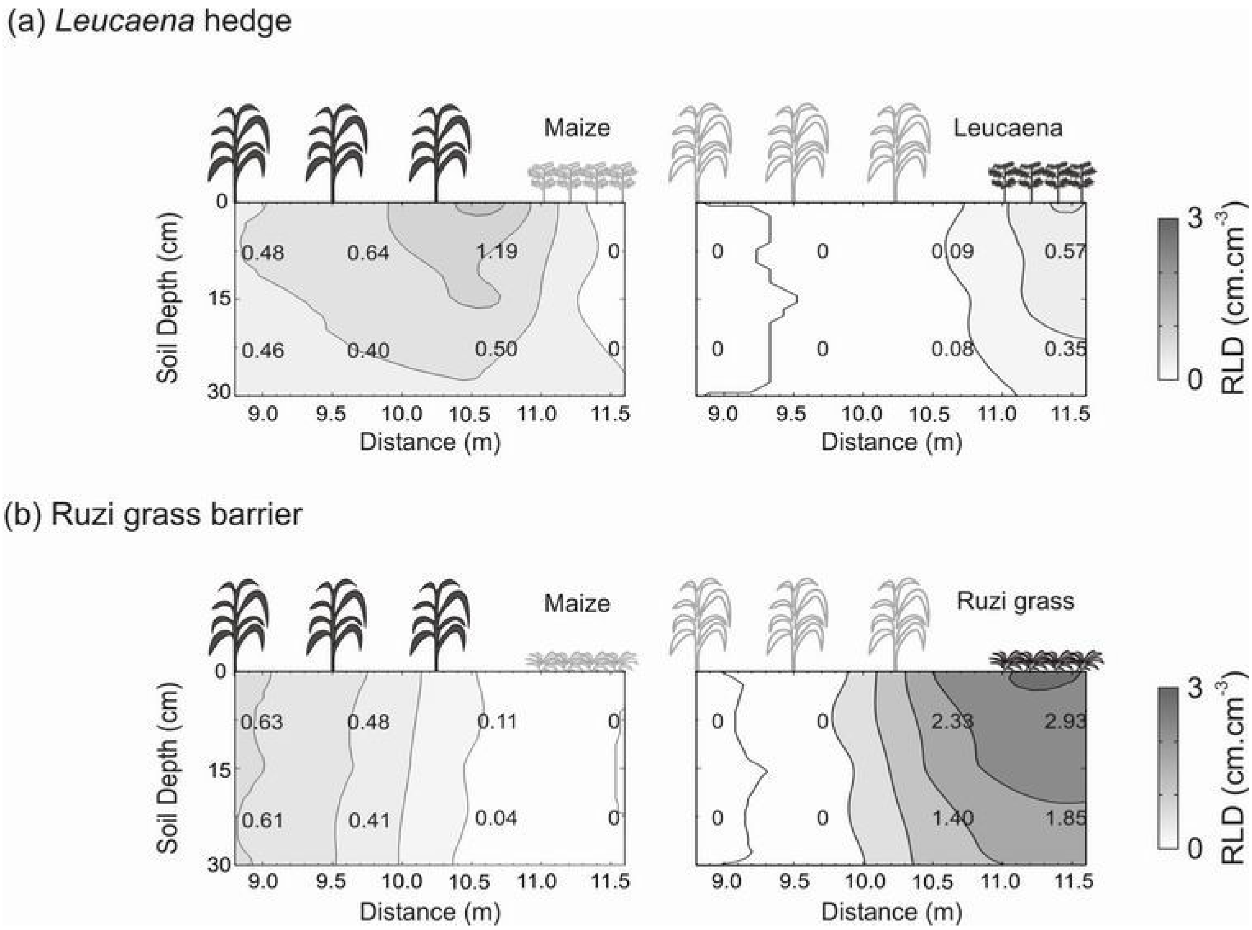


**Fig. 4.** Root length densities profiles as affected by soil conservation measure in cm cm³. Data were collected in plots without fertilizer application at Ban Bo Muang Noi, Loei province, Northeast Thailand in 2005.

Table 1 presents $\delta^{13}C$ of maize leaves at 100 days after planting (DAP). Higher values were observed in rows close to leucaena hedges than in the mid row position, indicating lower water stress than in the centre of the alley. This suggests that the decline in grain yield towards the barrier is not related with water deficiency. However, trends of $\delta^{13}C$ values in the ruzi grass treatment may point to the likelihood of water stress, particularly without fertilizer application, as values close to the grass barrier are much lower than in the treatment with leucaena hedges when compared to the mid row position. Further research to better understand the causes for the observed spatial variability in crop response in these systems is in progress.

**Table 1**. Effect of alley position on $\delta^{13}C$ values of the third youngest maize leaf at 100 DAP as affected by soil conservation measures and fertiliser application. Data were collected at Ban Bo Muang Noi, Loei province, Northeast Thailand in 2005.

| | Alley position | | | | | |
|---|---|---|---|---|---|---|
| | upper | | middle | | lower | |
| | Mid row | Barrier/hedge | Mid row | Barrier/hedge | Mid row | Barrier/hedge |
| **Leucaena hedge** | | | | | | |
| F+ | -10.821 | -10.712 | -11.063 | -10.787 | -10.860 | -10.726 |
| F- | -10.838 | -10.863 | -10.987 | -10.738 | -10.857 | -10.725 |
| **Ruzi grass barrier** | | | | | | |
| F+ | -10.787 | -10.679 | -10.790 | -10.747 | -10.766 | -10.702 |
| F- | -10.952 | -10.872 | -10.712 | -10.877 | -10.867 | -10.855 |

The calculation of the crop response index revealed well the above mentioned observations. Table 2 clearly indicates that fertilization had a strong effect on the crop response index. Furthermore, the negative impact of ruzi grass on maize yields is represented by the CRI values. The ruzi grass barrier system had a very negative CRI, indicting its poor effectiveness. The interaction showed similar trends, but it was less strong when fertilizer was applied.

**Table 2.** Crop Response index as affected by fertilizer application and soil conservation measure

| | Crop response index |
|---|---|
| **Fertilizer application (F)** | |
| + F | -2.77 a[1] |
| - F | - 11.96 b |
| **Soil conservation measures (SC)** | |
| Control without hedgerow | 0.07 a |
| Ruzi grass strip | -16.27 b |
| Leucaena hedgerows | -5.90 ab |
| **F x SC** | |
| +F | |
| Control without hedgerow | 0.13 a |
| Ruzi grass strip | -0.66 a |
| Leucaena hedgerows | -7.79 a |
| -F | |
| Control without hedgerow | 0.00 a |
| Ruzi grass strip | -31.88 b |
| Leucaena hedgerows | - 4.02 a |
| **Analysis of Variance** | |
| **F** | ** |
| **SC** | *** |
| **F x SC** | *** |

** P≤ 0.01, *** P≤ 0.001;
[1]values fallowed by the same letter are not significant different at P≤ 0.05 (Tukey`s test)

## Conclusion

Fertilizer application had significant effects on crop growth, mitigating negative effects of barriers.

Ruzi grass barriers showed a proliferate root growth, strongly interfering with maize in rows close to the grass barrier and a strong impact on maize growth in rows next to the barrier, especially when no fertilizer was applied. Leucaena had a moderate root distribution, interfering less with maize growing next to the leucaena hedges, making it more attractive than ruzi grass barriers.

The carbon isotope discrimination method can help to better understand cause of competition in barrier systems.

The CRI, based on simple aboveground observations, corresponded well with results from a detailed data analysis and seems to be a promising tool in this context.

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